PUBLICATION NO. 39. CODE WORD: ASPORTATO.

SECOND EDITION.

THE COMBINATION PROCESS

FOR

WORKING SILICIOUS AND SEMI-BASE ORES

CONTAINING

GOLD AND SILVER.

NOT A "NEW PROCESS," BUT A BETTER METHOD THAN IS GENERALLY EMPLOYED FOR EXTRACTING THE PRECIOUS AND BASE METALS FROM SILICIOUS ORES CONTAINING GOLD AND SILVER ASSOCIATED WITH THE BASER METALS.

BY

L. C. TRENT.
Mechanical and Metallurigical Engineer,
Member of American Institute of Mining Engineers.

WITH APPENDICES BY

WALTER McDERMOTT AND Messrs. GOODALE AND AKERS.

PUBLISHED BY
FRASER & CHALMERS,
Chicago and London.

THIS PAMPHLET IS ESPECIALLY DEDICATED TO

RAWLINSON TENNANT BAYLISS,

OF

LONDON, ENGLAND

WHO WAS THE MEANS OF BRINGING THIS PROCESS INTO PROMINENCE
AT THE WORKS OF THE MONTANA COMPANY, LIMITED,
MARYSVILLE, MONTANA, U. S. A.

COPYRIGHT BY
FRASER & CHALMERS,
1892.

PREFACE.

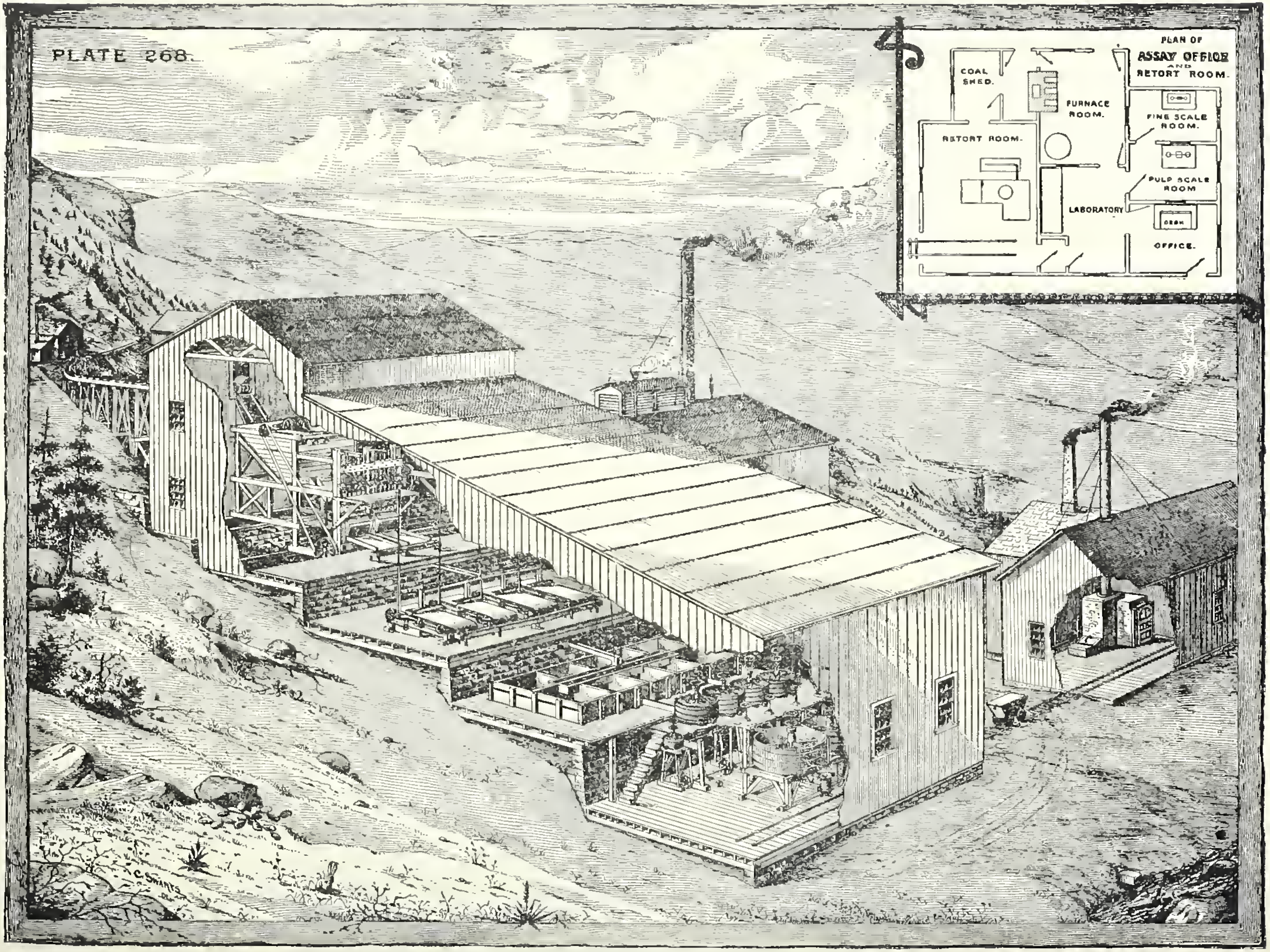
The author, recognizing the fact that present methods of milling are in most cases extravagant in cost of operation and inefficient in the saving of precious metals, presents this volume to the mining public with a hope that it will be closely studied by mine owners and managers.

While the method described is by no means new, yet it is comparatively unknown among those who could and should be benefitted by its use. I believe that there are a vast number of mines now working by more expensive and inefficient methods, that could by the Combination Process extract two dollars' worth of precious metals for the cost it now takes to produce one dollar's worth—with a higher percentage of saving and less first cost for plant.

In other cases ores could be reduced at the mines at less than half the present cost of transportation to smelting works.

SALT LAKE, UTAH,
MAY 1, 1892.

PLATE 268.



10 STAMP COMBINATION MILL,
FRASER & CHALMERS,
BUILDERS,

THE COMBINATION PROCESS

FOR

EXTRACTING THE VALUE FROM SEMI-BASE

GOLD AND SILVER ORES

COMBINATION PROCESS.

This is a method for the extraction of precious metals from ores that are not entirely "free milling" or "free amalgamating," *i. e.*, ores that will not yield all their precious metal contents without being previously "roasted" or "chloridized." There are many ores that are denominated free ores or "free milling ores," simply because it is demonstrated that it is more profitable to reduce by the simple method, raw amalgamation, and recover a less percentage of the precious metals, rather than adopt the more expensive method of roasting and chloridizing. Frequently the value of the increased percentage of extraction is more than offset by the greatly increased cost of the more expensive treatment and plant, which is three times as great for the same capacity per diem.

"The Combination Process" is a combination of well known methods of extracting the precious metals from ores. For ores containing gold associated with base metals it is necessary to pulverize the ores wet in a stamp mill and pass over amalgamated copper plates, which arrest all the free gold, and the pulp is then concentrated on **FRUE VANNING MACHINES** and the gold associated with the baser metals is saved in the form of a highly concentrated material, known as concentrations, which is readily sold to the smelting works or ore dealers. The above method is now universally adopted by all successful gold mines and is usually sufficient for ores low in gold containing no silver. Where ores contain silver as well as gold, it is necessary to continue the process further and to employ pan amalgamation to extract the silver not recovered by the concentrators.

Consequently the ores containing both gold and silver in equal or unequal proportions are first stamped wet and the free gold is saved by amalgamation on copper plates and the base metals containing silver and gold are extracted on the concentrators (Frue vanning machines). The tailings still containing the extremely fine gold and the silver in the form of chlorides are passed into settling tanks and the surplus water separated from the pulp, which is treated in the pans by the usual method of raw amalgamation. A large portion of the gold is recovered in the best of all forms, gold bullion.

The gold and silver associated with the baser metals, viz.: iron and copper pyrites, lead, zinc, antimony, etc., etc., are removed with the bases in a highly concentrated form, in a marketable condition, or for subsequent treatment suited to such material—chlorination, roasting and amalgamation, leaching by cyanide of potassium, or such other methods as are best adapted commercially to the surrounding conditions.

If the ores to be treated contain no gold, the same method is employed, omitting the amalgamation on copper plates.

In the above process three well known successful methods of extraction are employed, so arranged that all three cost but a trifle in excess of either. In a mill properly constructed the ore passes in at the top of the mill and through three operations by gravity, almost automatically—it being necessary to handle the ore once only from the settling tanks to the pans. The previous and subsequent manipulations are automatic.

Experience has shown that a limited percentage only of the precious metals contained in many ores can be extracted by concentration or amalgamation, and the amount saved by either method is not sufficient to justify the employment of the process singly. It must be understood that if all the mineral values in these ores were in the same condition, the values would all be extracted, or all not extracted, if either of the above methods was employed singly, but it invariably happens that the values in ores exist in different forms, some of which can be separated by concentration that usually will not yield to amalgamation. If free gold exists, which may be saved by either process, it is always better to remove this on the copper plates before the ore is concentrated, as it is more desirable to recover the gold in the form of gold bullion than in the concentrations.

Again, it frequently happens that much of the precious metal exists in the form of silver sulphides and chlorides of the different varieties, which cannot be concentrated, but can be readily amalgamated.

Again, flour gold often exists which is too light and fine to be caught on the copper plates or by the concentrators, but will readily yield to skillful pan amalgamation, and in all of these conditions the values will more readily amalgamate after the base metals are removed from the pulp by concentration, before going to the pans.

Experience has proved that usually an ore which will not yield to amalgamation may be easily separated by concentration, and an ore that cannot be concentrated will usually amalgamate in pans. An exception to this rule is occasionally found, but it will not often be encountered.

Ores too refractory to work by raw amalgamation, will frequently work well by the Combination Process while they would not work at all by raw amalgamation without previous concentration. For such ores as we have described above, the Combination Process is not only the cheapest but the most practical method of reduction.

The advantages of this method of extraction are manifold, viz.:

First.—Two-thirds at least of the capital required to erect plant is saved.

Second.—Eighty per cent. of the cost for wear and tear of iron and machinery is saved.

Third.—The cost of treatment by the Combination Process will never exceed one-third that of roasting and amalgamating, and will rarely exceed one-fourth.

Fourth.—It saves the loss of gold and silver by volatilization unavoidably incidental to roasting, and this is frequently a heavy loss, especially in ores containing gold.

Fifth.—A high percentage of the lead and copper contents of ores are recovered in a marketable condition and will frequently yield sufficient to pay the entire cost of separating the precious metals, and in all cases where these metals are present, will form a material item of product which would be entirely lost by treatment in a roasting mill.

Sixth.—The base metals are not only recovered to the profit of the mines but are also removed from the ore before being amalgamated in the pans, where they would seriously interfere with the process of amalgamation, in addition to causing a heavy waste by fouling and flouring the quicksilver.

Seventh. The base metals are removed while the pulp is in the proper condition to admit of concentration, as after the pulp is amalgamated, the bases are so pulverized by grinding and decomposed by the action of the chemicals in the pans, as to make successful concentration impossible, even if the highly diluted state of the pulp and the irregular flow of the water from the settlers would admit of concentration, which it would not, as it is a well known fact that the successful concentration of tailings flowing from an amalgamating mill is nearly impossible.

Eighth.—The removal of the base metals from the ores before they are amalgamated enables a fine bullion to be produced from base ores, making a material saving in the cost either of refining the bullion or expressing it to market.

Ninth.—The manifest simplicity of the process, combining as it does only well known methods of extraction, dispenses with the necessity of expensive technically-trained assistance. The requisite skill and knowledge required for the successful employment of the "Combination Process" may be obtained in any mining camp.

Tenth.—All elements of uncertainty consequent upon and incidental to the selection of a suitable process for the treatment of ores, are eliminated, as all the methods are so well known and successful as to remove any doubt in the minds of any one experienced as to the benefits to be derived from the whole in combination.

Eleventh.—The capital is saved, which is required for the immense storage of wood or other fuel used in the roasting process, and the continual risk of fire consequent on such large storage of fuel, causing not only the loss of capital invested, but also jeopardizing the safety of the reduction works is avoided.

Twelfth.—The capital is saved which is required to purchase and store salt requisite for any roasting process, and this is a large item where the mines are remote from railway, making it necessary to keep six months' supply stored at the mines, for use during the winter months.

NOTE.—While the Combination Process requires the use of salt, it is not over 25 per cent. of the amount required where chloridizing is employed, consequently the surplus investment of capital is saved.

Thirteenth.—The water discharged from a combination mill is not so objectionable on account of fouling streams as the water from a chloridizing mill, which not only discharges more objectionable material into the streams, but also discolors the water to such an extent as to cause an outcry from settlers along the stream below the mill.

Fourteenth.—In the Combination Process, wet crushing is employed as against dry-crushing by the chloridizing mill, the latter method being very injurious to the health of employes, as well as to the machinery. The loss from depreciation in value of plant is three times as great in the dry-crushing mill as in the wet-crushing mill.

Fifteenth.—In a custom mill it is a great safeguard in working a new ore because in treating any variety of milling ore, a reasonable percentage of the values will be saved, even if it may be found after a trial that it would be more profitable to chloridize.

A custom mill equipped with the Combination Process would be able to treat successfully a greater variety of ores to a profit.

Wherever raw amalgamation is employed to extract the value from gold or silver ores, the concentration of the pulp after leaving the copper plates, or its concentration previous to entering the pans may be profitably practiced. By its use some additional saving will always be had, and the additional cost incidental thereto will never exceed 25 cts. per ton of ore treated. It must always be considered that the cost of mining, transportation, crushing and partial extraction must be paid, leaving only the addition of the insignificant sum named and the interest on the slightly increased cost of plant to offset the greater saving of precious metals and the recovery of valuable base metals, besides the saving of quicksilver and the advantage accruing from the increased fineness of the bullion. The cost of all these advantages will in no case exceed a tithe of the benefits derived.

The cost of treatment of ores by the "Combination Process" is compared with treatment by roasting and chloridizing at railroad points in the Rocky Mountain region of the United States. Of course the cost will vary some at the different points, depending on local conditions, but the average will be about as below:

Treatment of ores by a chloridizing and amalgamating mill having a capacity of 50 tons of ore per day.

COST OF TREATING 50 TONS DAILY OF ORES CONTAINING ASSAY VALUE $25.00 PER TON IN GOLD AND SILVER.

BY

CHLORIDIZING, ROASTING AND AMALGAMATING.

Cost of 50 tons per day at $11 per ton		$550.00
Total assay value of 50 tons of ore	$1,250.00	
Less loss by volatilization, 5 per cent. in roasting before amalgamation	62.50	
	$1,187.50	
Less average loss in amalgamation, 12 per cent	142.50	
	$1,045.00	
Less cost of treatment	550.00	
Net result 50 tons		$495.00

Or $9.90 per ton net if $25 ore is received.

COST OF TREATMENT OF 50 TONS OF ORE PER DAY

BY

COMBINATION PROCESS.

Cost of treatment of 50 tons of ore per day by Combination Process at $3.50 per ton		$175.00
Gross value of 50 tons $25 ore	$1,250.00	
Less loss on treatment, 20 per cent	250.00	
	$1,000.00	
Less cost of treatment	175.00	
Total net results from 50 tons $25 ore		$825.00

Or $16.50 per ton from the Combination Process against $9.90 per ton from the chloridizing mill process, or $330 per day additional profit to a mine extracting and working 50 tons of ore per day.

In the above calculation, we have allowed a loss of 5 per cent. in volatilization from the chloridizing mill, which in practice is below the average, and if much gold is present the loss will be considerably greater from that cause.

We have allowed a loss of 12 per cent. in the process of amalgamating, which is below the average loss in amalgamating mills.

In calculating the loss in the treatment by the Combination Process, we have allowed 20 per cent. for loss in treatment. While this is greater than it should be from the process itself, it must be remembered that a part of the product from the Combination Process is in the form of concentrations, and the excess in the estimate of loss is intended to cover the cost of treatment of the concentrations.

In comparing the value of the two methods of treatment, the difference in the cost of the plant necessary should also be taken into account.

The average cost of erecting a forty-stamp dry-crushing chloridizing mill is about $160,000, while the cost of a twenty-stamp mill for the Combination Process would, on the same basis, not exceed $65,000.

The above comparison is made of mills having the same capacity per day.

In the treatment of lower grade ores, the advantage in favor of the Combination Process is still more apparent, as ores containing by assay as low as $12 or $15, can be handled to a good profit, while the cost of the operation in a chloridizing mill would consume the entire value contents of these lower grade ores.

Heretofore we have made all our comparisons with treatment in a chloridizing mill; we will now attempt to show the advantage of mines erecting their own reduction works in place of selling their ores to the smelting works and ore buyers.

As all the mines are differently situated, local circumstances govern the cost of freight to an ore market. We cannot make any table that will fit all situations, but will assume that on ores that are suitable for this method of treatment, the cost of freight to the ore market and the smelter charges will aggregate $22 per ton. This will be rather below than above the average of such charges.

Net value one ton of ore, if sold to smelter:

Assay value one ton of ore		$25.00
Freight and smelting charges	$22.00	
Sampling	1.00	
Freight paid on moisture	.50	
Smelter's deductions, 5 per cent	1.25	
Total deductions	$24.75	

This leaves practically nothing to cover the cost of mining, and for profit; while on the basis of previous figures, it is shown that a ton of $25 ore can be made to yield $16.50 per ton after deduction of working charges and loss in treatment.

We will make two other comparisons. It will be shown by the first that $25 ore will yield as much profit treated on the spot by the Combination Process as $40 ore would if sold to smelters, where the smelting charges are as stated in the last comparison.

Net yield of $40 ore, where sold to smelters or ore buyers:

One ton ore, assay value		$40.00
Less freight and smelting charges	$22.00	
Less freight paid on moisture	.50	
Smelter deductions, 5 per cent. assay value	2.00	
Total deductions		$24.50
Leaving as net result from $40 sold to smelters		$15.50

Or $1 per ton less than $25 ore would yield if treated by the Combination Process.

Approximate net yield of $40, if treated by Combination Process:

One ton of ore assay value		$40.00
Less 20 per cent. loss on treatment	$8.00	
Less cost of treatment	3.50	
Freight to mill	1.00	
Total deduction		$12.50
		$27.50

Which would leave a total net yield of $27.50 from one ton of $40 ore as against $10.50 if the ore was sold to smelters.

We will make one other comparison to show that the process is also adapted to very low grade ores as well as the medium grades, and that ores as low grade as $10 per ton will yield a moderate profit, providing they are not burdened with a heavy mining expense, and the mill is close to the mine.

One ton of ore, assay value		$10.00
Loss in treatment 20 per cent. on assay	$2.00	
Cost of treatment	3.50	

Leaving a margin of $4.50 per ton to pay for mining, and for profit.

Of course the business of mining such low grade material exclusively would not offer sufficient inducements to engage in the business, unless there were large bodies of ore, so as to handle immense quantities. But it invariably happens with mines producing the higher grades of ores, that much of the lower grade material must be removed to obtain access to the richer grades; besides, if a profit could be made from the lowest grades after being mined, it would remove the necessity of extra care in selecting the ores before going to the mill, which is frequently a large item of expense in mines carrying variable grades of ore.

The estimates of cost for working ores by this method as herein given will of course vary somewhat, and will be governed by local conditions, such as cost of labor, fuel and salt, and distance from railway, but in the most extreme cases the cost will not be increased more than $1.50 per ton over the figures given.

To the estimated cost of treatment must always be added the cost of freight from mine to mill. If a mill is to be built, it is always best to build near the mine, and modern inventions now in most cases make it possible to locate the mills at the mines, if it is thought desirable.

If water is absent, it is cheaper to pump the water to the mines than it is to transport the ore to water, even if the water has to be pumped several miles and to a great elevation. It is possible to pump water any distance and to any elevation. It is cheaper to build a pump and pipe line than it is to construct any sort of a tramway, and it is also cheaper to operate the pump than to operate a tramway.

If water power is to be had at a distance from the mine and not at the mine, the power to operate the mill can be transmitted to the mine by electricity.

If it is expensive to haul fuel to the mine for steam power, the steam power can be placed at a point most convenient to obtain fuel, and the power be transmitted to a mill at the mine.

The Combination Process, like all other methods of ore reduction, must be skillfully handled, the capacity of the concentrators must be ample, and we regard the Frue Vanning machine as essential to the success of this method of ore treatment. It must be employed in all cases where the "Combination Process" is used. The delicate action of this famous machine has made this simple method of ore reduction possible. No more than five tons per 24 hours should be passed over each machine, and even a less amount will repay the extra outlay for the additional machines required. The machines should be carefully adjusted, skillfully handled and kept clean; to obtain the best results from the Combination Process, it is necessary to make a clean separation of the bases from the pulp before it goes into the amalgamating pans. Consequently when the ore to be treated contains a great deal of base material, it would be well to pass the pulp from each five stamps over an improved (corrugated belt) Vanning Machine and afterwards divide the pulp or tailings on two or three ordinary Vanning Machines, the number to be regulated by the amount of pulp to be handled. By this arrangement the material is concentrated twice, first by the improved Vanning Machine, which removes the heaviest of the bases and last by dividing the pulp so concentrated over the ordinary Standard Vanning Machines. Such an arrangement will insure accurate and satisfactory extraction of both the precious and base metals by the Combination Process.

In the selection of a process adapted to any particular ore, there is no need of committing an error, if ordinary precautions are taken. If any doubt exists of the suitability of a method of reduction for any particular ore, a practical test can usually be had by sending sufficient ore (not less than a car load) to some mill where the process to be tested is used, and have the test made on a practical scale. If a test of this kind cannot be had, there are several testing mills, which have the appliances and the skill requisite to make a test on any process that the owner of the ore may desire.

No definite instructions can be given as to the best method of amalgamating, because it depends entirely on the character of the ore to be treated. The operation, to be successful, requires an experienced amalgamator, who will soon determine that question, but a word of advice may be given to those attempting the amalgamation of ores containing both gold and silver.

It is well known that the re-agents used in the pans, necessary to amalgamation of silver ores, rather detract from than assist the amalgamation of gold; consequently when such an ore is to be amalgamated, it will materially assist the amalgamation of the gold to put a little quicksilver in the pans and let the gold be amalgamated before the chemicals are added to assist in saving the silver. Experience has proved this a valuable expedient in amalgamating a mixed gold and silver ore.

The Combination Process was first used at the Cibolo mine in Texas and the results were always satisfactory in the highest degree. The ore is a semi-base ore carrying silver and a little gold, associated with lead and iron pyrites. A portion of the precious metals are associated with the base metals named. This is separated by concentration, and the remainder is in the form of sulphide of silver, which is decomposed in the pans and saved by amalgamation.

MONTANA MINING COMPANY, LIMITED.

This company, owning the famous Drum Lummon Mine, have 120 stamps operating by this process; sixty stamps work the lower grade ores by plate amalgamation and subsequent concentration, and the higher grade ores (those assaying above $12 per ton) are treated by the full Combination Process, employing copper plates, concentration and pan amalgamation.

The ores contain both gold and silver (the latter predominating), associated with iron and copper pyrites; and a portion of the silver is in the form of sulphides with which some gold is associated.

The success of the Combination Process at this mine is very marked, the percentage of saving is high, the bullion is extremely fine (above .950) and the concentrations are rich, averaging over $1,000 per ton. The company admit owing their success to the introduction of this process. A statement from the officers of the company is appended.

Extract from report of John Darlington, consulting engineer, at the directors' meeting, September 17th, 1886:

"CONCENTRATION OF BATTERY PULP (21).—The concentration of the battery pulps before amalgamation has been attended with most favorable results. (1.) The sulphides (obtained as concentrates) render the pulp fairly clean for the pans. (2.) The bullion, instead of being low, is brought to a high degree of fineness. (3.) It has led to very important and valuable saving of mercury in the pans; and in melting the crude bullion, to a material reduction in the weight of 'granulations' or metallic slag."

Extract from address of Mr. John Bayliss, director of the company, on his return from an inspection of the mine, October, 1886:

"It was part of my duty to ascertain the amount expended upon all the works from the date of your resident manager's second arrival at Marysville down to the time of my departure from Marysville, and I will give you the full details of the principal items. * * * You shall then judge as to the prudence of the investments. First, the Frue Vanners. Those Vanners and the buildings have cost you £5,000. This system of concentration before amalgamation was adopted after a series of experiments and investigation during some months. It has been most successful, and one profitable result has been to increase the fineness of the bullion you produce from .550 fine, as it was by the old process (raw amalgamation without concentration) to .930 to .950 fine, as it is now. * * * A considerable saving is also effected by the extraction of the base ore in the process of concentration before amalgamation in the pans, and you are getting in round figures—now, I am saying this deliberately—you are getting by the present process $3 to $4 per ton of ore treated more than you would if you reverted to the old process. This on 3,000 tons per month is some £28,800 a year, on an outlay of £5,000. * * * But this is not all, for the present process, coupled with the praiseworthy efforts of your officers to economize in every way, has resulted in reducing the loss of quicksilver from 1.55 lbs. per ton to .8 lbs. in June and .62 lbs. in July. Now taking the average of these two months—I will not assume we are always going to have July figures—it makes in round figures this difference, that for every ton of ore you treat the loss in quicksilver is ¾ lbs., as against more than 1½ lbs. by the old process, and this condition of things, taking quicksilver at 50 cents per lb., represents £2,500 per annum."

THE COMBINATION MINING AND MILLING CO.,

Owning the Black Pine Mine near Phillipsburg, Montana, introduced the Combination Process, after the unsuccessful attempt to treat their ores by raw pan amalgamation. While using the latter method the saving of precious metals was low (below 60 per cent.) and the bullion was base, being only about .500 fine. Since the introduction of concentration previous to amalgamation, the average saving of precious metals has been increased to 85 per cent. and the bullion fineness is raised above .800, and notwithstanding the average value of the ores is below $20 per ton, the concentrates have an assay value of $150 per ton. They are chloridized in a Bruckner furnace and amalgamated in the pans, so that this entire product is in the form of bullion.

The ores contain silver associated with lead, carbonate and galena, also copper, iron pyrites and carbonate of copper with silver associated in the form of sulphide. Since the introduction of the Combination Process, the company has been very successful, and in 1891 the capacity of the mill was doubled to twenty stamps, which have a capacity of 60 tons of ore per day.

LONE PINE MINE,

Situated in Montana has also recently adopted the Combination Process, after attempting raw amalgamation with indifferent success. The new method has been in operation but a few months and the company are more than satisfied with the process, and are engaged at the present time in increasing their capacity by adding additional stamps. By raw amalgamation only about 50 per cent. of the values were saved, while the present method extracts a full average of 85 per cent.

THE MAGINISS MINE,

Situated at Maiden, Montana, was among the first to adopt this process, after vainly attempting to treat their ores, first by plate amalgamation, and afterwards by pan amalgamation, neither of which methods was successful in saving over 50 per cent. of the precious metals. The ore contained mainly gold, associated with about 3 per cent. of carbonate of lead, which was separated by the concentrators, together with a large proportion of the gold, the remainder of which was easily amalgamated in the pans after the lead had been separated; and while the bullion was not fine, being only about .350, a very high percentage was extracted. The concentrations, which carried 60 per cent. of lead and $750 in gold, formed a very satisfactory and easily marketed product. This mine was extremely prosperous for several years.

WEBSTER MINING AND MILLING CO.,

Situated at Marysvale, Utah, have also adopted the Combination Process. The ores from this mine contain both gold and silver to the average value of about $35 per ton, $10 of which is gold. The ore as milled contains an average of 8 per cent. of lead in the form of galena and carbonate. The concentrators save a product averaging 50 per cent. of lead and $100 in gold and silver, which is sold to the smelters, the lead contents yielding more than sufficient to pay smelting charges. At these works fully 85 per cent. of the values is recovered and fine bullion is made.

THE WASHINGTON MINE,

Situated at Bonanza, Idaho, also uses the Combination Process. We are not informed of the results, only that it is operating satisfactorily.

THE BIG OX MINING CO.

Own a mine situated near Marysville, Mont., and have recently erected a ten-stamp combination mill, which has been in operation several months. The hopes of the company are more than realized, and notwithstanding they have a very base ore the extraction is above 85 per cent. of the precious metals, besides which the concentrates contain much lead and some copper, which is a source of revenue as well as the gold and silver.

GOLDEN LEAF MINING CO. (LIMITED),

Situated at Bannock, Mont., also use the Combination Process, and while no actual data are at hand the process is very skillfully handled, and the results are very gratifying to the company.

We have said but little in this pamphlet about the cost of reducing the concentrates, because it is difficult to apply any general estimate on account of the great variation in the value and quantity of this product. In some cases the concentrates will only represent one one-hundreth of the weight of the original ore treated, while in other cases they will represent as much as one-eighth. In the former case the cost of treating the concentrates per one ton of ore treated would be infinitesimal; in the latter case it would add a material sum to the cost unless the concentrates contained much valuable base metal, *i. e.* lead or copper. This would usually be the case, as with the Webster Mining & Milling Co., whose lead values more than pay the cost of extracting the precious metals from the concentrates.

We have not enlarged upon the fact that the first cost of a combination mill per ton capacity is far less than one-half the cost of a chloridizing mill of the same capacity, although this of itself is important. The Combination Process is the only practical method of reducing ores at the mines that recovers the inferior as well as the precious metals.

The Combination Process could be applied to good advantage to work the tailings from many of the coarse concentrating mills, as frequently the tailings from such mills are quite rich and contain the values in a form in which they could be saved by the Combination Process.

In any well-regulated coarse concentrating mill the tailings from the jigs should be pulverized fine under stamps or in a Huntington mill or a Chilian mill, and the product from these mills re-concentrated on a Frue Vanning machine. After this it would frequently be profitable to continue the process further by milling the tailings produced, in amalgamating pans.

It would be well for parties using coarse concentrating mills, who are not saving a high percentage of the precious metals, to examine into the merits of this process.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

CONCENTRATION BEFORE AMALGAMATION FOR LOW-GRADE, PARTIALLY-DECOMPOSED SILVER ORES. WITH NOTES ON THE GEOLOGY OF THE FLINT CREEK MINING DISTRICT.

BY C. W. GOODALE, BUTTE, MONT., AND WILLIAM A. AKERS, PHILLIPSBURG, MONT.

The treatment of silver ores of too low a grade to justify either smelting or preliminary roasting, and yet not "free" enough to permit of raw amalgamation, has ever been a serious problem. As bearing upon it, the operations of the Combination Mining and Milling Company of Black Pine, Deer Lodge County, Mont., during the past year may not be without interest. It is not claimed that the process to be described is not susceptible of great improvement, nor is any claim of originality made for it; but its use is, as yet, not very general, and it seems to offer a means of profitably working the large class of partially-decomposed argentiferous ores which, by reason of their low grade, demand some cheap, continuous process for their profitable treatment.

As introductory to the occurrence of the ores, a brief general statement regarding the geological peculiarities of the entire district may not be amiss, since it is the home of two of America's greatest silver producers, the Granite Mountain and the Bi-Metallic mines, and bids fair to achieve even more prominence in the mining world than it already possesses.

On the east side of the Flint Creek valley, four miles back from the base of the foot-hills, and elevated about 2,500 feet above them, is a rugged chain of mountains, heavily timbered in places, and covered with immense masses of granite which have broken off from greater elevations and rolled down their sides. Within a few hundred feet of the summit of one of these peaks is situated the Granite Mountain mine, and immediately below it, on the same vein, the Bi-Metallic. The strike of this vein is nearly due east and west and its dip from 8° south to 8° north of the vertical. Near its apex the walls are of very hard granite, dark-gray in color, and bear evidence of movement in the polishing of their surfaces. In width the vein at this point varies from 2 feet to 18 feet, the ore being separated from both walls by a clay selvage and the chutes dipping westerly. In depth the vein widens out from 50 feet to an extreme of 150 feet, the pay being confined to a ribbon of ore running through it of from 2 feet to 22 feet in width. A number of times in the past it has been thought that the vein forked, but in every instance these supposed splits proved, upon investigation, to be merely due to immense "horses" of granite. At no point does the vein actually crop, nor is it common to find the pay-chutes nearer than 100 feet to the surface. On the western slope of the mountain, where the vein is not water-shedded, the ore gives unmistakable evidences of leaching, and, in consequence, the first chute encountered in running the adits was too low in grade to pay; but after passing through this and driving several hundred feet on a pinched and perfectly barren vein a second and very rich chute was encountered. Upon the discovery of this second or "Bonanza" chute, as it was called, miners were at once put stoping, and from 1,435 tons treated in a custom mill the company realized $273,897.81, and the erection of a 20-stamp dry-crushing mill was at once begun. In grading out for the retort-house the top of another chute was encountered and this, in depth, has proven to be one of the richest and most extensive yet discovered in the mine. Subsequently, the Bi-Metallic Mining Company, controlled by the men who had been instrumental in the purchase and development of the Granite Mountain mine, located a shaft distant over 1,000 feet from the extreme western workings of the latter, and sent it down to the 200-foot level before cross-cutting. The vein was there and drifting soon caught the pay-ore, and now, with a three-compartment shaft sunk to the 800-foot level and long drifts in both directions from the shaft every 200 feet, it bids fair to equal, if not excel, the Granite Mountain mine itself. Connection has been made between the drifts of these two companies, and the joint level opens up a trifle over 6,000 feet on the vein.

About two miles west of the Granite Mountain mine, and on a general northerly and southerly course, is a contact between two distinct geological formations. On the west the formation consists of limestone, shale and quartzite of the older series, probably Cambrian, while east of this contact, including the higher portion of the mountain range, the country rock is an eruptive granite of a much later geological age than the bedded formations along its flanks. This is made manifest by the crushing and crumpling of the bedded rocks and the penetration of them by the spurs of granite at various points immediately west of the contact. Further proof of the eruptive character of the granite is furnished by the remarkable chemical changes produced in the limestone and shales along and near this contact and extending, in some instances, 1,000 feet or more west of it. Along this metamorphic belt the purer bands of limestone have been changed to marble and the impure or shaly lime-beds made vitreous in some places and at others changed to epidotic and garnetiferous beds. The granite partially overlies the bedded rocks along its west flank. This is to be observed at many places where explorations have been made along the contact. The dip of the latter is invariably to the east under the granite. Gash veins extend westerly from this contact as far as the chemical and thermal influences of the granite have made any marked changes in the crystalline structure of the beds, but beyond these limits of metamorphic changes the fissures disappear. There is a broad zone of mineralized limestone extending along the contact from 20 feet to 60 feet in width, containing large bodies of manganese ore carrying more or less silver.

In the limestone west of the contact is located the oldest mine in the district. A section of the hill, as revealed by shafts and diamond drill-holes, shows the first 50 feet to be a yellow, magnesian limestone, under which and immediately over the vein is a layer of shale from an inch to a foot in thickness. The width of the vein is very variable, running from a mere seam to 24 feet. Forming the footwall is a stratum of mottled limestone from 2 feet to 3 feet in thickness and under this a stratum of very hard, white limestone. Next follows a 7-foot zone of black limestone; then from 10 feet to 25 feet of mottled limestone; then from 2 feet to 3 feet of barren quartz, and underlying all a very compact limestone of a jet-black color, which the deepest diamond drill-hole, 642 feet from the surface, failed to pierce. The strata dip to the north at an angle of 32° from the horizon. No fossils or evidences of organic life have ever been found in the limestone. In the old stopes, opened fifteen or twenty years ago, small stalactites and stalagmites have formed. The strike of the vein is east and west, and in dip it is conformable to the stratification of the country. Developments in this mine, which have been quite extensive, have revealed four principal faults, all at right angles to the strike of the vein, the latter term being employed merely as a matter of convenience and not to define its precise character. Going west on the strike of the vein from the extreme eastern workings, the ore drops 92 feet at the first fault, has its regular strike for a distance of 60 feet, faults up 65 feet, is unbroken for 50 feet, drops 18 feet, has its strike again for 45 feet and then drops 265 feet. In all four of these faults the plane of fracture is more or less inclined and in every instance the hanging of the fault drops.

All the cañons opening into the Flint Creek Valley bear testimony to the erosive effects of the glaciers which have ground their way down them, and small terminal moraines have been deposited at their mouths. In the Boulder cañon, the largest tributary to the Flint Creek, opening into it about twelve miles north of the town of Phillipsburg, the marginal moraines are very heavy, and the terminal moraine, located at the confluence of the two cañons, is three miles long and from one to two miles wide. This moraine is elevated but slightly above the surrounding country, and is composed of round granite boulders, few of them being of any great size. The largest one measured contained 1,000 cubic feet. There is nothing to lead one to suppose that the Flint Creek Valley was ever the bed or track of a glacier, nor is there any way of determining the character of the rock under the valley, which varies from one to two miles in width; but on the western foothills extensive ruins of red sandstone are to be noticed.

In the range of mountains west of the Flint Creek Valley and distant from it about ten miles are situated the mines of the Combination Mining and Milling Company. The formation in this locality varies considerably, being in some places a friable, laminated sandstone, and in others metamorphosed into a quartzite. In places it is slightly micaceous. In all cases the strata dip in a westerly direction and at an angle of 20° from the horizon. The strike of the vein is north and south and in its dip it is comformable to the stratification of the sandstone.

Going west on the dip of the vein from its apex, five faults have been encountered thus far, the strike of which is with the strike of the vein, or north and south. At the first one, 100 feet down on the vein from its apex, the ore is faulted up 35 feet, and for 100 feet it has its regular dip; then it drops 15 feet, is unbroken for 40 feet, is carried up 10 feet, continues without a break for 50 feet, drops 10 feet, is regular again for 130 feet, and is then raised 25 feet. At right angles to this series are two other faults 50 feet apart, the vein being dropped 20 feet at one and elevated the same distance at the other. Eighteen minor faults, where the vein is only shifted 2 or 3 feet have been encountered during the past year. In all these displacements, great and small, the plane of fracture is always more or less inclined, and in every instance the hanging-wall of the fault has gone down. Whenever our workings on the vein have encountered a fault, there being no evidence of any horizontal squeezing, we have always followed this law, and have been invariably successful in finding the vein beyond it. In a number of instances upon striking a fault, we have continued our regular developments in opening up the mine without going to the expense of raising or sinking simply to find the vein beyond it, knowing that it was sure to be either above or below its former position as the inclination of the fracture indicated, and laying out our work accordingly. While this practice may be condemned as being too risky, in actual results it has been the means of saving the company hundreds of dollars for dead work—an important factor in the commercial success in mining a low-grade ore. With the smaller breaks the fracture is clean and abrupt, the walls of the faults being polished by mutual abrasion, and pressing one against the other; but in the more important ones the distance between walls is from 1 to 3 feet, the fissure being filled with talc, decomposed country rock, small boulders of sandstone and black manganese. In the last fault mentioned as crossing the strike of the vein this is not the case, the walls being from 6 to 10 feet apart, and the filling-matter consisting of a decomposed quartz gangue carrying from 25 to 75 ounces of silver and one-tenth of an ounce of gold to the ton. This fissure as far as developed seems to be bounded above and below by sandstone walls; although in every particular save this it is a regular fault, the vein south of it entering at its bottom and passing out of it to the north at its top. It would seem that the silver has concentrated in this crevice between the upper vein north and the lower vein south, and that the ore-body has been formed by substitution in a fault the sides of which were originally close together. In this crevice the ore is attached to the walls on all sides, and small pockets of it fill irregular shaped cavities in the walls.

Taking an average of the vein exposed during the past year, its width will not exceed 2 feet, its greatest size being 4 feet and its smallest 6 inches. It is usually laminated in structure, bands of from 6 to 18 inches of decomposed ore assaying from 20 to 200 ounces silver to the ton being attached to both foot and hanging walls, and the middle portion of the vein consisting of quartz, more or less barren. It has been noticed that where the country rock was hard and tight, the vein was always pinched and impoverished, and no change for the better occurs without a concomitant change in the walls of the vein.

The following analysis, made by Messrs. Von Schulz and Low, of Denver, from a sample of the mill battery for the month of October, 1888, will show the character of the ore:

Qualitative tests gave silica, carbonic acid, sulphur, iron, copper, lead, antimony, arsenic, zinc, manganese, silver, gold, a little chlorine, a little mercury, doubtful traces of cobalt, and very small amounts of calcium, magnesium and soda.

The same sample by quantitative analysis gave:

Silica	per	cent.,	84.09
Sulphur	"	"	0.19
Iron	"	"	7.05
Copper	"	"	1.31
Lead	"	"	1.01
Zinc	"	"	0.30
Manganese	"	"	0.35
Antimony	"	"	0.66
Silver	"	"	0.08
Arsenic	"	"	0.05

In gold the ore runs 0.0000857 of 1 per cent., or 50 cents to the ton. In connection with the analysis of the Combination ores we quote the following remarks of President Richard Pearce: "The Combination ore is of a very curious nature. My attention was directed to it some six years ago, and I then discovered hübnerite (tungstate of manganese), and a very rare mineral, pseudomalachite (phosphate of copper), and these finds were noticed in the *Transactions* of the Colorado Scientific Society. The presence of P_2O_5 in the ores is suggestive of the origin of the deposit; it must have come from the adjoining rocks. We know of no phosphides which correspond with the arsenides of copper. Arseniates of copper can always be accounted for by the oxidation and alteration of enargite into arseniates." Our attention having been called to the presence of hübnerite by Mr. Pearce, a determination was made by Messrs. Von Schulz and Low from a sample of concentrates, 20 tons into 1, which gave 0.33 per cent. tungsten.

THE MILLING.

The mill, as originally constructed by Messrs. Fraser & Chalmers for the Black Pine Mining Company, was an ordinary 10-stamp, wet-crushing mill, with room left between the battery and settling tanks for concentrating machinery should it be found necessary to add it. As illustrating the impracticability of working these ores by raw amalgamation alone a short summary of the operations of the Black Pine Mining Company may be given.

The mill was started on the 16th of July, 1887, and the run lasted until the 14th of September of the same year. During this period there were treated 1178 dry tons of ore, assaying 17.5 ounces, and obtaining 20,615 fine ounces silver. Of this amount there was recovered in the form of bullion 9,482.90 fine ounces, or 46 per cent. of the battery assay.

We need only note the points of difference between the Combination Company's plant and the form of mill ordinarily employed for treating silver ores of the class usually termed "free milling." These, as is well known, are so called more because their low grade precludes their profitable treatment by the various other more efficient but vastly more expensive methods, than because they are better adapted to that process.

The ore is stamped, passed over four Frue Vanners, the light pulp that goes over their "tails" being settled in tanks, shovelled into pans, and there amalgamated, discharged into settlers, and the resultant amalgam strained, retorted and melted in the usual manner. An analysis of these concentrates for the month of October, 20 tons into 1, gave the following results:

Silica	per cent.,	32.50
Lead	" "	9.10
Copper	" "	8.22
Sulphur	" "	1.19
Zinc	" "	0.81
Silver	" "	0.54

Samples of the pulp going to the pans for the same month showed that it contained:

Copper	per	cent.,	1.05
Lead	"	"	0.48
Zinc	"	"	0.25
Sulphur	"	"	0.09
Silver	"	"	0.05

For the year ending May 31, 1889, the details of milling were as follows:

Dry tons crushed		9,061.965
Average assay, ounces of silver per ton		22.67
Gross contents of ore, ounces of silver		205,434.75
Estimated per cent. of reduction		80.70
Estimated product		165,785.84
Dry tons concentrates produced		541.805
Average assay of concentrates, ounces of silver per ton		136.17
Silver in concentrates	73,777.55	
Silver in bullion	97,660.60	
Total fine ounces		171,438.15
Actual per cent. saved		83.45
Total cost of milling		$39,537.61
Average cost per ton		$4.36

Batteries in service, 347 days, 5¾ hours.

Average ore crushed per stamp in 24 hours, 2.612 tons.

An analysis of the cost of treating one ton for the year gives the following figures:

Labor and superintendence	$25,821
Salt and other chemicals	2,955
Fuel, at $1.00 per cord	1,944
Castings and iron	3,846
Oils and illumination	1,066
Quicksilver	4,915
Miscellaneous supplies and team in yard	3,084
Total	$43,641

When the mill was started by the present management, an assay of the escaping slime water was made, showing the value of the slimes carried by it to be 52 ounces in silver to the ton, or more than double the silver contents of the original ore. A series of carefully conducted experiments were at once inaugurated, and from them it was learned that three tons of those slimes, dry, containing 156 ounces of silver, were passing through the waste gate from the settling tanks every 24 hours. These slimes were too light to permit of their being thoroughly settled by even the most extensive system of tanks, and to check this heavy loss a China pump was placed in the last of the series of slime tanks. This pump discharges into a small tank placed above and immediately in front of the mortars. It is only one foot deep, being made shallow in order to prevent the gradual settling of slimes in it, and the consequent necessity of cleaning it out from time to time. From the side of this tank, and near its bottom, is the 2-inch pipe for supplying the water to the stamps. The only purpose of this tank is to furnish water to the stamps at uniform pressure. By prohibiting the use of any clear water in the battery, the escape of these slimes was very materially reduced, but this of itself was not enough to stop all overflow, as it would be in an ordinary wet-crushing mill, for reasons which will be explained later on.

The immediate effect of turning back into the battery, say two tons every 24 hours of slimes carrying twice as much silver as did the original ore (and this proportion of values has always existed), was to heavily "salt" our battery sample, and as the most rigid economy was essential to the commercial success of the property, the question of securing any accurate check on the mill became momentous. After careful consideration, it was decided to adopt the following system: Night and day samples are taken from the battery launders in the usual manner, and are assayed daily with the other mill samples, but the results are corrected by the salting for the previous month. To determine this percentage, it is simply necessary to obtain the actual battery assay, and this is secured from the data furnished by the balance of the mill work, after the monthly averages are made up, in the following manner: The number of tons crushed, minus the number of tons of concentrates produced, must equal the number of tons amalgamated. The number tons amalgamated, multiplied by the average assay pan sample, must be equal to total silver contents of the pulp amalgamated. This, added to the total silver contents of the concentrates produced, secured in the same manner, gives the grand total of fine ounces of silver in the ore. This divided by the number of tons crushed gives the actual battery assay. In this computation all tons are dry tons. The percentage of salting thus determined varies slightly, but the fluctuation is due more to errors in sampling than to any change in the actual amount of the salting. Usually, this is about 5 per cent.

But there was still a heavy loss in the escape from the settling tanks of water carrying rich slimes, owing to the introduction of water at the heads of the vanners. To stop this, a small jet pump, using steam from the boilers and supplied with 50 feet of steam hose for a discharge, was placed at the tanks, and slime water used in lieu of clear water for thinning down the pulp in the pans. While this corrected the evil, it also had the effect of increasing the difficulties in the way of concentration, as, in order to stop all overflow from the tanks, only as much water could be used on the heads of the vanners as was pumped into the pans, plus the evaporation.

After much experimenting it has been found, that with the limited quantity of water that can be used on the vanners, a speed of 180 revolutions of the crank shaft per minute, with a belt travel of 3⅓ feet per minute, and an inclination of 3½ inches in the length of the machine, gives the most satisfactory results on these ores, although intelligent and constant adjustment is rendered necessary by reason of the changes occurring from time to time in the character of the pulp treated.

By reference to the details of milling for the year ending May 31, 1889, it will be noticed that the mill overran its assay 2.49 per cent. or 5144.63 ounces. As the actual battery assay is determined by the assays of average pan and concentrate samples, and as the pan sample is of necessity taken before the rich slime water is pumped into the pans for the purpose of thinning down the pulp, the mill is bound to overrun, presenting perfect accuracy of sampling and assaying, exactly the amount of that part of the silver contained in the slime water used in the pans which is amalgamated. As the greatest care is exercised to secure the most accurate sampling possible, and as in the assaying no deduction is made for silver in litharge, except in the tailings sample, the amount that the mill overran may safely be credited to the use of slime water in the pans.

The pan charges have been changed constantly, according to the character of the pulp treated, and the amalgamation tests have been many and varied. The charge now being used, which seems to be the best tested, is 50 pounds of salt, 2 pounds of sulphuric acid, and ½ pound of cyanide, with 100 pounds of quicksilver strained in after the pan has been running 4 hours. The temperature of the pulp is raised by steam to 180° Fahrenheit, and the charge is run at 65 revolutions per minute for 8 hours. Settlers are run 14 revolutions per minute, and give good agitation with 3-inch shoes.

In the battery, 40-mesh brass-wire screen-cloth has been used during the past year, with the exception of about two weeks, when 30-mesh was tried by way of an experiment. After a thorough test it was found that the loss occasioned by higher tailings exceeded the profit accruing from increased crushing capacity, and the 40-mesh screens were replaced. The falling off in the savings during the time the 30-mesh screens were in use was largely owing to the fact that the difference between the very finest of the slimes and the coarse particles that would pass through a 30-mesh screen was so great that with the increased quantity of pulp to be treated by the vanners, they could not be made to do close and clean work.

The concentrates produced, which thus far have been the final product, have been shipped to a smelter for treatment; but experiments are now in progress looking to their treatment at home, and it is highly probable that the necessary machinery will be added to the plant in the near future.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

COMBINED AMALGAMATION AND CONCENTRATION OF SILVER ORES.

BY W. MC DERMOTT, NEW YORK CITY.

(Read at the New York Meeting, February, 1885.)

It is well known that many so-called free-milling silver ores are so classed more from their value necessitating a cheap process than from a real adaptability to raw amalgamation. Such low-grade ores, carrying more or less sulphurets, are more profitably treated by a cheap rapid process than by the more effective but costly process of roasting and amalgamation. The tailings are sometimes crudely concentrated, or after lying and becoming partially oxidized, are again worked in pans. Of late years, by the use of improved methods of concentration, many old low-grade tailings-piles have been reworked to a good profit; and in some improved mills arrangements are made to concentrate before or after amalgamation, thus making a single treatment in mill suffice.

It is self-evident that on a low-grade ore a small increase in percentage saved is of no commercial advantage if accompanied by a material increase in cost, and therefore a cheap and continuous system of work is the real necessity if a fair saving is to be effected. As an illustration of the possibilities of combined concentration and amalgamation on some ores, the following results of a working test at the New York Ore-milling and Testing Works will be of some interest.

The ore treated was a hard white quartz from Mexico, carrying a very small percentage of finely divided sulphurets, chiefly iron pyrites. The original average assay was 35.5 oz. silver and 0.125 oz. gold per ton. The ore was stamped wet through a 40-mesh screen and passed direct to the Frue vanner. The concentrates produced were about one per cent. of the original ore, *i. e.*, 100 tons into one.

The concentrates assayed 1,397 oz. of silver per ton and 5.2 oz. of gold per ton. The tailings from the vanner assayed 16.04 oz. silver per ton and 0.05 oz. gold. The tailings were run into a settling tank and afterwards worked by regular pan amalgamation, yielding bullion .858 fine, and the settler tailings assayed 4.1 oz. silver per ton with a trace of gold. The combined process yielded, therefore, about 89 per cent. of the assay value. In this test about one-third of a ton only was operated on and a certain quantity of ore remained in the battery which was weighed and assayed and proved to be concentrated to a value of about $100 per ton in gold and silver. It may safely be assumed that the precious metals which concentrated in the battery would in regular running be found in the concentrations and bullion to the same percentage as those in the discharge of the battery. But should this method of calculation be objected to, the following figures based on actual yield of test are reliable:

Bullion value in original ore by assay		$14.51
Bullion value of ore left in battery		3.41
Bullion value of ore discharged and treated		$11.10
Value of concentrations by assay	$5.77	
Value of bullion from pan	3.81	
Value of total yield		9.58
Loss by difference		$1.52
Bullion value of settler-tailings by assay		1.42

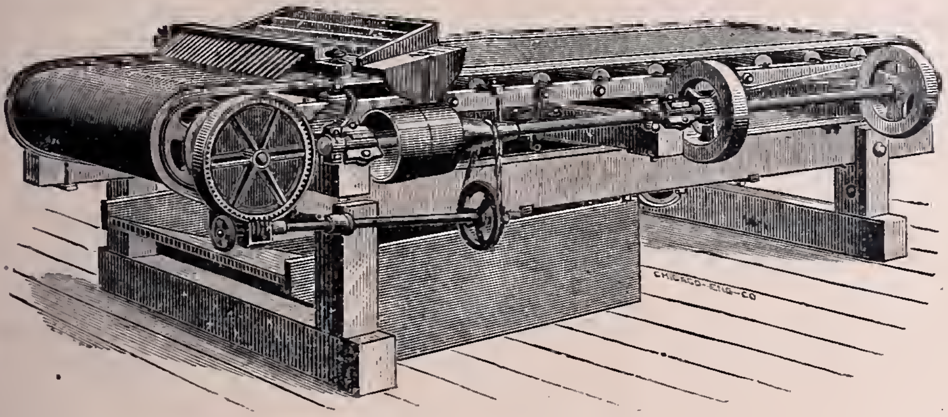
Of course it is not possible to clean up accurately in a small test either the few pounds of rich concentrates, or the small quantity of bullion from the pan; but a substantial agreement of yield with the differences between assay of original ore and tailings justifies confidence in the result of the test. The samples of tailings from both concentrator and settler were taken by automatic sampling machines, and the settler sample was further checked by a sample taken from the pan just before discharge. These points are mentioned as an excuse for basing calculations as to working processes on so small a test, in which, however, it is to be noted that the actual operation was exactly the same as it would be on a large scale. The stamp battery was fed by automatic feeder; the concentration was automatic and similar to that in any good gold mill; the pan charge was run but six hours with a small quantity of bluestone and salt.

In speaking of the percentage of value saved as 89, two assumptions are made, viz.: First, that the residue in battery was from the fact of its concentration as susceptible to treatment as the discharge of the battery; second, that the contents of the rich concentrates constitute a final product. These assumptions are correct enough for the general purposes of this paper. The percentage of loss in subsequent reduction is of course very small per ton of original ore crushed. The additional cost of concentration in a properly arranged mill for amalgamation is extremely small, as it necessitates, even in a 40-stamp mill, not more than two extra men in twenty-four hours, with a consumption of but trifling power. If continuous amalgamation be employed, the whole process is of course cheapened still more. The process is adapted to low grades of ore carrying sulphurets, which it is not advisable to roast; and even some higher grades, under certain local conditions will yield better commercial results than by any process involving a preliminary roasting. The disposition of the small quantity of rich concentrates is determined by local conditions; the product can either be roasted and put through the pans, smelted with other ores or shipped to reduction works. The roasting of a small, rich product is of course a very different matter to roasting the whole of the crude ore and can be done in a small, cheaply built reverberatory furnace. Where the ores and local conditions favor, raw leaching by the Russell process can take the place of amalgamation, leaving the same work of utilizing the sulphurets to the concentrators.

PLATE 254.

THE FRUE ORE CONCENTRATOR.

FRASER & CHALMERS, CHICAGO, ILL.



The most perfect modern appliance for concentration of slimes and finely crushed material: for treatment of gold and silver tailings; and direct concentration of ores of silver, lead, copper, tin, zinc, etc., after stamps or pulverizers. Automatic, and making perfectly clean mineral concentrates at one operation.

Especially adapted to low grade silver ores and gold mill tailings.

Nearly 10,000 are now in use, giving entire satisfaciton.

Saves from 50 to 100 per cent. more than any other concentrator in use.

The wear and tear is merely nominal; the water required is less than by any other wet concentrator; the power required per machine is less than one-half horse power; the labor required is light, and one man on a watch easily attends to sixteen machines.

FRASER & CHALMERS,
CHICAGO & LONDON.

"WRITE TO FRASER & CHALMERS, CHICAGO, ILL., FOR MACHINERY AND SUPPLIES DESCRIBED IN THIS CATALOGUE.

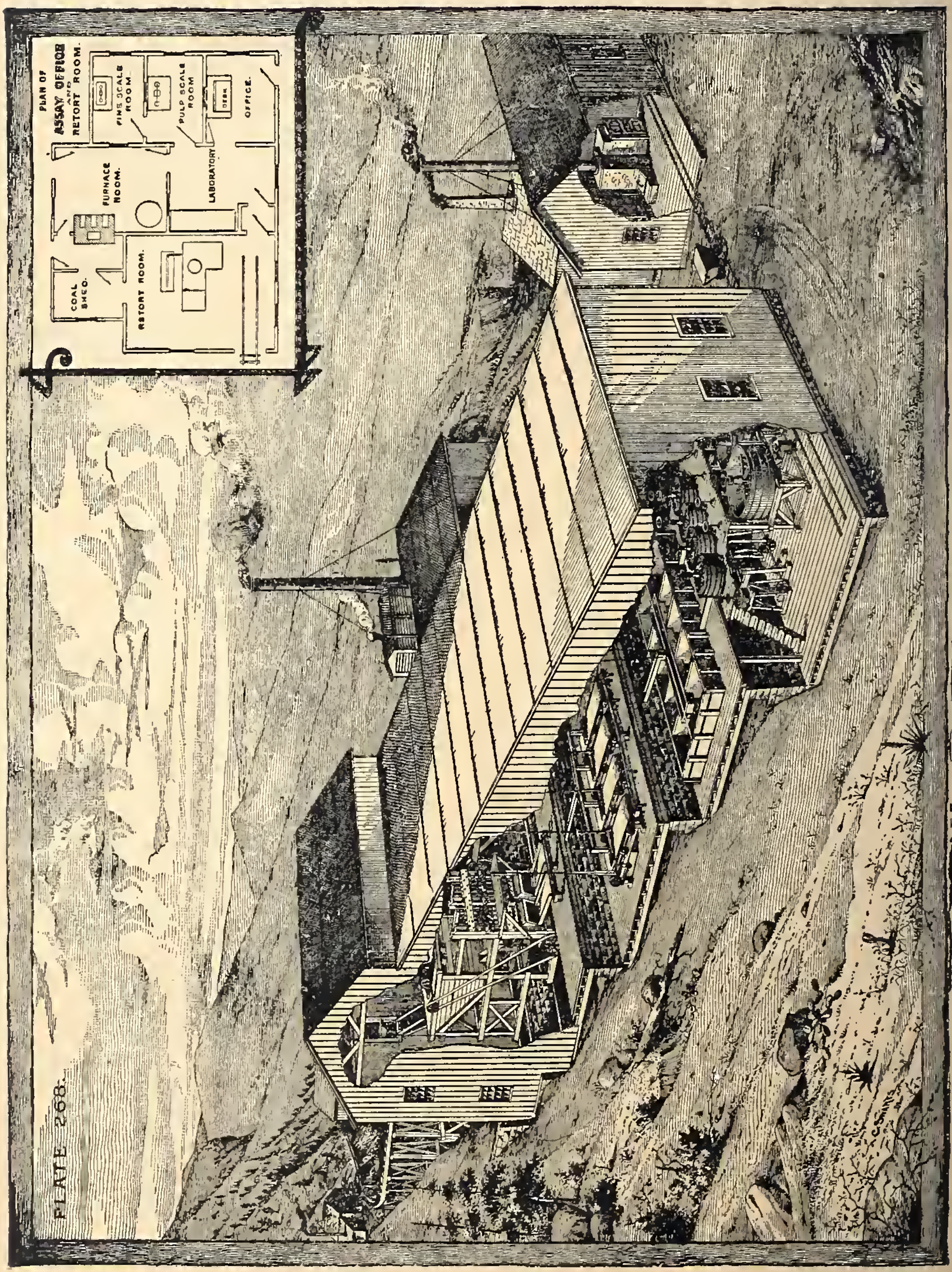

PLAN OF ASSAY OFFICE AND RETORT ROOM.
FINE SCALE ROOM.
PULP SCALE ROOM.
DESK
OFFICE.
FURNACE ROOM.
LABORATORY
COAL SHED.
RETORT ROOM.

PLATE 268.

10-STAMP COMBINATION MILL. FRASER & CHALMERS, CHICAGO.